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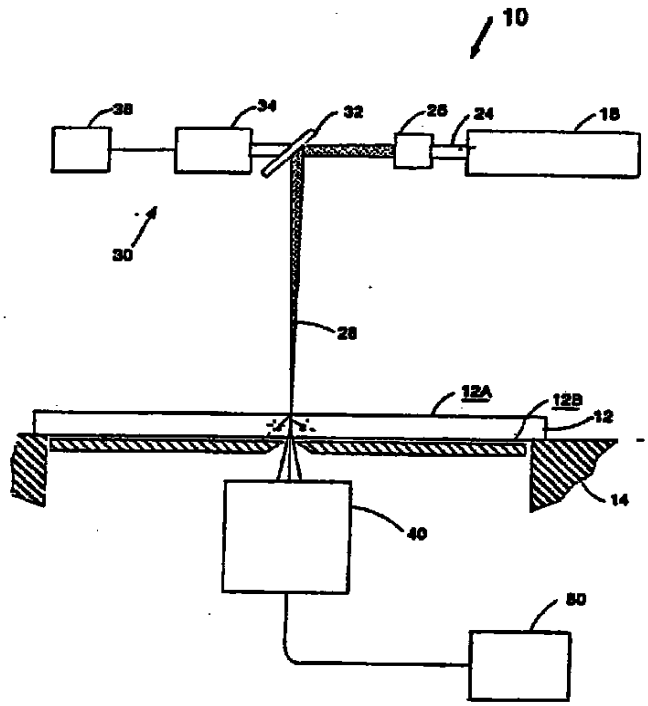
(54) Title: APPARATUS FOR READING A TRANSPARENT PHOTOSTIMULABLE LUMINESCENT SCREEN



(57) Abstract

Apparatus (10) for reading a transparent PSL screen (12) includes a mask (60) with a slit (62) for preventing secondary emissions (S) from reaching the photodetector (40).

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TITLE

Apparatus For Reading A Transparent Photostimulable Luminescent Screen

Field of the Invention

The present invention relates to an apparatus for reading a transparent photostimulable luminescent screen and, in particular, to a reading apparatus which includes a mask to prevent the impingement of secondary radiation on a photodetector.

Background of the Invention

Photostimulable luminescent imaging systems are known. Such systems utilize a photostimulable phosphor sheet that is exposed to image producing x-ray radiation to produce a latent image pattern in the phosphor sheet. The latent image is read out by scanning the phosphor screen with a relatively long wavelength beam of interrogating radiation, such as the beam generated from a helium-neon laser. The interrogating radiation stimulates the phosphor to emit radiation from the phosphor, typically light at a blue wavelength. The emitted radiation is detected, typically with a photomultiplier tube, and thereby converted into an electrical signal. The signal may be converted to a series of digital picture element values and stored in such form in a suitable memory for later retrieval and display.

Two types of photostimulable phosphor screens are known, a scattering type screen and a transparent screen. The first type, the so-called scattering type, is exemplified by United States Patent Re. 31,847 (Luckey). A scattering type screen is one which scatters the stimulating radiation, resulting in relatively high stimulation efficiency. Although it is the most common screen in use today, the scattering type suffers from limited spatial resolution because, when manufactured thick enough to absorb an appreciable fraction of the x-rays, scattering causes image degradation. Spatial

resolution is the ability to resolve small, closely spaced details in the image. Spatial resolution is usually expressed in terms of line-pairs-per-unit-distance.

Apparatus for reading scattering type photostimulable luminescent screens is also well known. Representative of such devices are those disclosed in United States Patent 4,346,295 (Tanaka et al.) or United States Patent 4,742,225 (Chan). When reading a photostimulable luminescent screen the signal to noise ratio (S/N) of the reading system is important, it being recognized that high efficiency for collecting the emitted light is desirable.

Chan recognizes that a high percentage of the stimulating beam may be reflected from the photostimulable phosphor screen and then be re-reflected, as by the collection optics, back to some other area of the photostimulable screen, thus stimulating the phosphor to emit from this other location. This unwanted stimulating light is termed "flare" and the flare induced emission of light is termed "prestimulation." Prestimulation degrades the quality of the obtainable image. Accordingly, the device shown in the Chan patent incorporates a mask having a slit aperture in the collection system to reduce the effect of flare.

The second type of photostimulable luminescent screen is a so-called transparent type, as exemplified in United States Patent 4,316,817 (Cusano et al.). Although the phosphor disclosed in this last mentioned patent is not photostimulable, the chemical activation process to make this phosphor photostimulable is well known. See for example United States Patents 4,608,190 (Brixner) or 4,261,854 (Kotera, et al.) This type of screen is, as its name implies, substantially transparent to the stimulating radiation, although it may be somewhat scattering to the emitted radiation, and offers the potential for better spatial resolution than the scattering type screen.

Although the signal to noise ratio of the reading system for a transparent screen is important, another factor has been identified that limits the spatial resolution achievable with

transparent photostimulable luminescent screens. It is recognized that the mean free pathlength of the stimulating radiation in the photostimulable phosphor is quite long. Since no material can be perfectly transparent, a small portion of the stimulating beam is scattered into the phosphor and may travel a significant distance before stimulating emission. Theoretical analyses as well as experimental results have shown that about one-half of the total light emitted from a transparent screen is stimulated by this small scattered portion of the interrogating radiation beam regardless of the degree of transparency of the screen.

In very transparent screens few photons are scattered away from the spot of interrogating radiation. But, because the mean free path is very long, these photons can travel a large distance in the screen and therefore have a large probability of stimulating a luminescent site. In less transparent screens the mean free path is shorter, but more photons are scattered from the spot of interrogating radiation so the probability of stimulating luminescence away from the beam is approximately the same. This behavior is markedly different from that of scattering screens in which all the stimulated luminescence arises from the immediate neighborhood of the spot of interrogating radiation.

It is therefore believed advantageous to prevent emitted radiation from the small scattered portion of the stimulating radiation beam from reaching and being detected by the photodetector.

Summary of the Invention

The present invention relates to apparatus for reading a transparent photostimulable luminescence (PSL) phosphor screen having a first and a second major surface thereon and having image information stored therein. The apparatus includes a platen for supporting the screen and a source of interrogating radiation disposed adjacent to the first major surface of the screen. Means is provided for focussing the radiation to a diffraction limited spot. Means is also provided for scanning the spot of radiation along a

predetermined path across the first major surface of the screen, the scanning radiation exciting the phosphor in the screen along the path to emit primary radiation in accordance with the image stored therein. The primary radiation exits the screen from both the first and the second major surface thereof. The phosphor in the screen causes a small portion of the interrogating radiation to scatter and thereby to emit secondary radiation from other portions of the screen, the secondary radiation also exiting from both major surfaces of the screen. A photodetector responsive to both primary and secondary emitted radiation is disposed adjacent to the second major surface of the screen.

In accordance with a first embodiment of the present invention the apparatus includes a slit mask disposed between the second major surface of the screen and the photodetector, the slit in the mask being aligned with the path to permit only the primary emitted radiation from the second major surface to impinge the photodetector.

Since maximizing the collection efficiency to improve signal to noise is important to achieve high image quality, it has been found that in accordance with a more detailed embodiment of the present invention a second light collection system to collect the emitted light transmitted through the screen is desirable. To this end the use of a slit aperture in a mask to prevent the collection of light emitted from other than the instantaneous scanning point improves the spatial resolution achievable with the transparent screen.

Brief Description of the Drawings

The invention will be more fully understood from the following detailed description thereof, taken in connection with the accompanying drawings, which form a part of this application and in which:

Figure 1 is a stylized pictorial representation of an apparatus for reading a transparent photostimulable luminescence screen having a mask positioned in accordance with the present invention;

Figure 2 is an enlarged view of a portion of Figure 1 illustrating the generation of primary and secondary radiation; and

Figure 3 is a view similar to Figure 1 illustrating the apparatus with a second mask positioned in accordance with a second embodiment of the present invention.

Detailed Description of the Invention

Throughout the following detailed description, similar reference numerals refer to similar elements in all Figures of the drawings.

With reference to Figure 1 shown is a stylized pictorial representation, partially in section, of an apparatus generally indicated by reference character 10 for reading a transparent photostimulable luminescence (PSL) screen 12. Suitable for use as the screen 12 is that disclosed in United States Patent 4,316,817 (Cusano et al.) although other suitable screens may be used. This last mentioned patent is hereby incorporated by reference herein. The screen 12 has first and second major surfaces 12A, 12B respectively thereon. The screen has image information previously stored therein.

The apparatus 10 includes a platen or support platform 14 which form means to support the screen 12 in a predetermined position. As will be developed any suitable screen support arrangement may be utilized and remain within the contemplation of the invention.

The apparatus 10 includes a source 18 of interrogating radiation, such as a helium neon laser such as that manufactured by Jodon Lasers of Ann Arbor, Michigan and sold by model HN20G. The source 18 is disposed adjacent to the first major surface 12A of the screen 12. The source 18 produces a beam 24 of stimulating radiation which is focussed by optical means 26 to produce an

interrogating beam of radiation 28 that is focussed to a diffraction limited spot.

Scanning means 30 directs the focussed interrogating beam 28 along a predetermined path across the first major surface 12A of the screen 12 The scanning means 30 includes a mirror 32 driven by a drive motor 34 powered by a drive-source 36.

When operating in a transmissive mode, as illustrated in Figures 1 and 2, a photodetector 40 is disposed adjacent to the second major surface 12B of the screen 12. Suitable for use as the photodetector 40 is the photomultiplier sold under model number 9635B by EMI Industrial Electronics of Ruislip., Middlesex, England.

As is believed best seen in the diagrammatic view of Figure 2 the interrogating radiation, as it scans the screen 12, excites the phosphor therein and causes the same to emit primary radiation schematically indicated by reference character P. The intensity of the primary emission P is in accordance with the image stored in the screen 12. A portion of the primary radiation P exits the screen 12 from both the first and the second major surfaces 12A, 12B thereof, as shown at 44 and 46, respectively. The phosphor in the screen 12 causes a small portion of the interrogating radiation to scatter, as at 48. The scattered radiation travels through the screen 12 and causes the phosphor in other regions thereof to emit secondary emissions S. The secondary emissions S are depicted by dotted lines. A portion of the secondary emissions S also exits from both the first and second major surfaces 12A, 12B of the screen, as at 52, 54, respectively.

The secondary emissions S, if permitted to reach the photodetector 40, degrades the image obtainable therefrom and, for this reason, is believed to be disadvantageous. In particular, the spatial resolution of the apparatus is compromised.

In accordance with the present invention the apparatus 10 further includes a mask 60 having a slit 62 therein is disposed between the second major surface 12B of the screen 12 and the photodetector 40. The mask 60 is mounted on suitable support abutments 64 in any convenient fashion in the position between the second surface 12B of the screen 12 and the photodetector 40. The slit 62 in the mask 60 is aligned with the path of the interrogating radiation 28 to permit only the emitted primary radiation P exiting at 46 from the second major surface 12B to impinge upon the photodetector 40. The presence of the mask 60 prevents secondary emissions S exiting at 54 from the second surface 12B of the screen 12 from reaching and being detected by the photodetector 40. As a result improved spatial resolution of the image is obtained.

In some instances it is desirable, to increase the collection efficiency of the apparatus and thereby further improving the signal to noise ratio, to position a second photodetector 40' proximal to the first major surface 12A of the screen 12. The outputs of both the first and the second photodetectors 40 and 40', respectively, are connected to a suitable image storage device, such as an image memory 80. The second photodetector 40' is conveniently mounted in any suitable manner. In accordance with a second embodiment of the invention a second mask 70 having a slit 72 therein is mounted on suitable support abutments 74 in any convenient fashion to position the second mask 70 between the first major surface 12A of the screen 12 and the second photodetector 40'. The slit 72 in the second mask 70 is also aligned with the path of the interrogating radiation 28. The second mask 70 functions to permit only the emitted primary radiation exiting at 44 from the first major surface 12A to reach the second photodetector 40'.

It may thus be appreciated that the presence of the second mask 70 prevents secondary emissions S exiting at 52 from the first surface 12A of the screen 12 from reaching and being

detected by the photodetector 40'. As a consequence the spatial resolution of the image obtainable from photodetector is also improved.

Those skilled in the art, having the benefit of the present invention as set forth herein may effect numerous modifications thereto. It should be understood, however, that such modifications should be construed as lying within the scope of the present invention, as defined by the appended claims.

WHAT IS CLAIMED IS:

1. Apparatus for reading a transparent photostimulable luminiscence phosphor screen having image information stored therein, the apparatus having

a platen for supporting a transparent photostimulable luminescence phosphor screen having image information stored therein, the screen having a first and a second major surface thereon,

a source of interrogating radiation disposed adjacent to the first major surface of the screen;

means for focussing the radiation to a diffraction limited spot;

means for scanning the spot of radiation along a predetermined path across the first major surface of the screen, the scanning radiation exciting the phosphor in the screen along the path to emit primary radiation in accordance with the image stored therein, the primary radiation exiting the screen from the second major surface thereof, the phosphor in the screen causing a portion of the interrogating radiation to scatter and thereby to emit secondary radiation from other portions of the screen, the secondary radiation also exiting from the second major surface of the screen; and

a photodetector responsive to both primary and secondary emitted radiation, the photodetector being disposed adjacent to the second major surface of the screen;

wherein the improvement comprises:

a slit mask disposed between the second major surface of the screen and the photodetector, the slit in the mask being aligned with the path to permit only the primary emitted radiation from the second major surface to impinge the photodetector.

2. The apparatus of claim 1 wherein the primary radiation also exits the screen from the first major surface, wherein the apparatus further includes

a second photodetector disposed adjacent to the first major surface of the screen, the improvement further comprising:

a second slit mask disposed between the first major surface of the screen and the second photodetector, the slit in the second mask being aligned with the path to permit only the primary emitted radiation exiting from the first major surface to impinge the second photodetector.

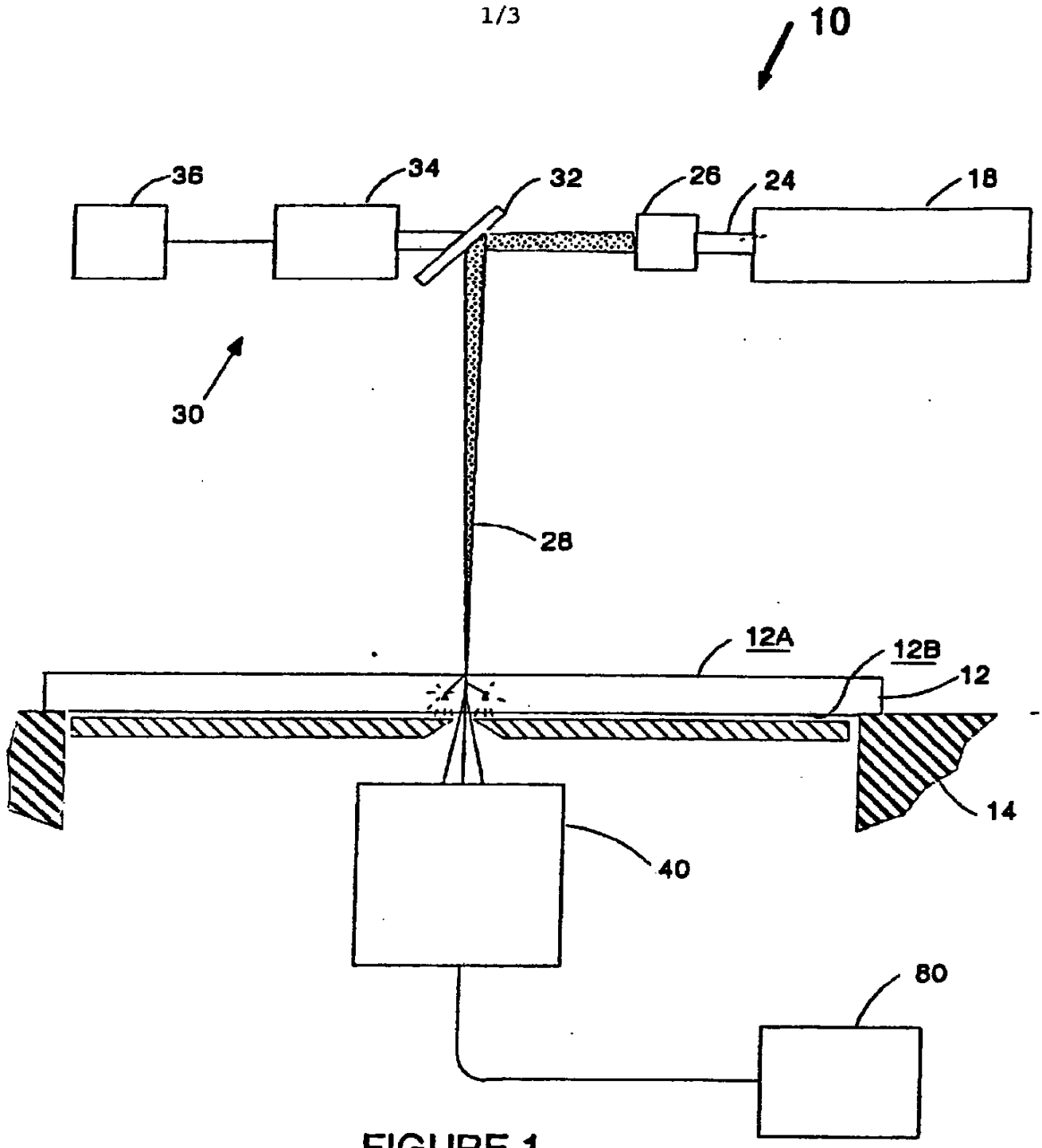

FIGURE 1

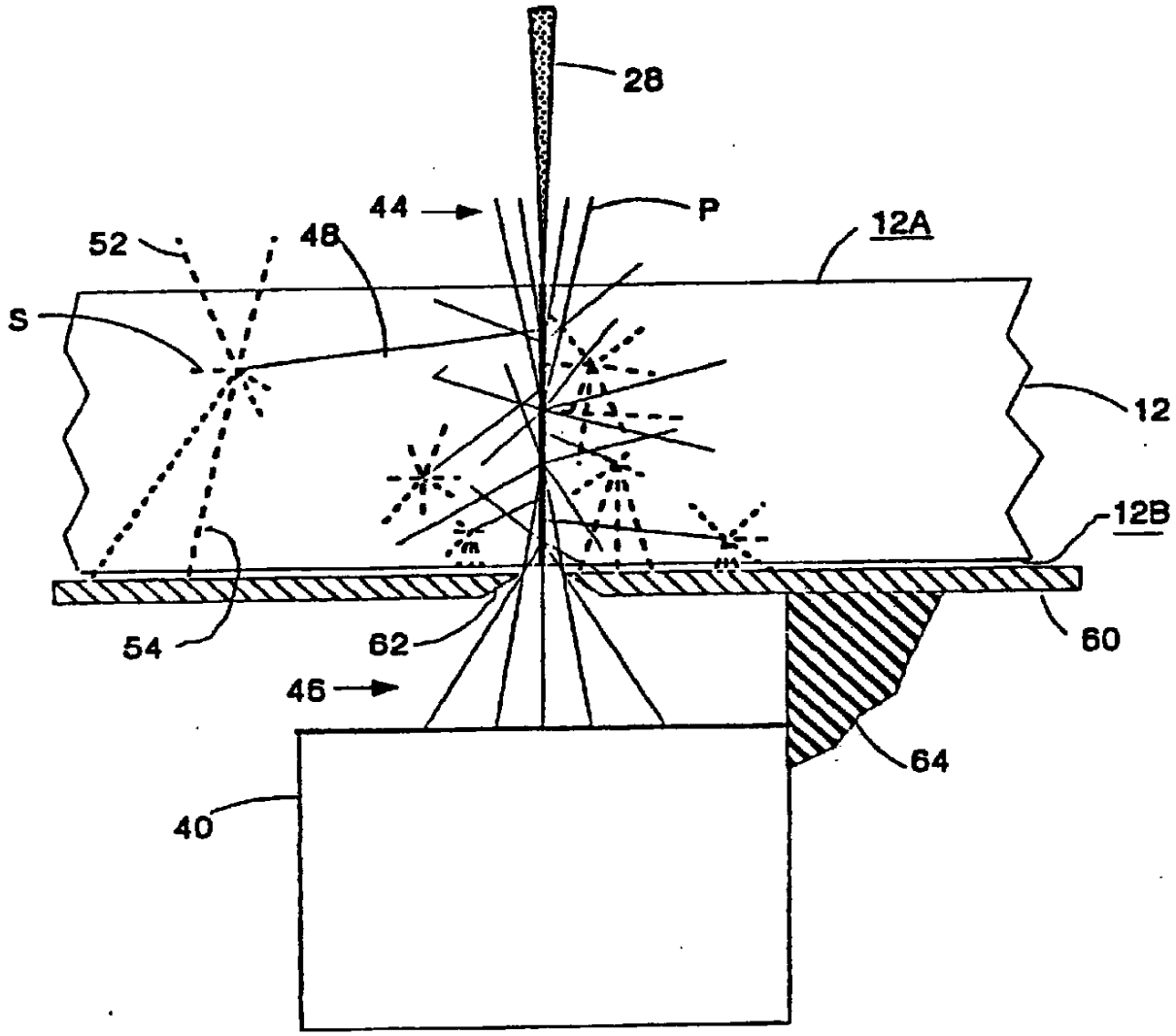

FIGURE 2

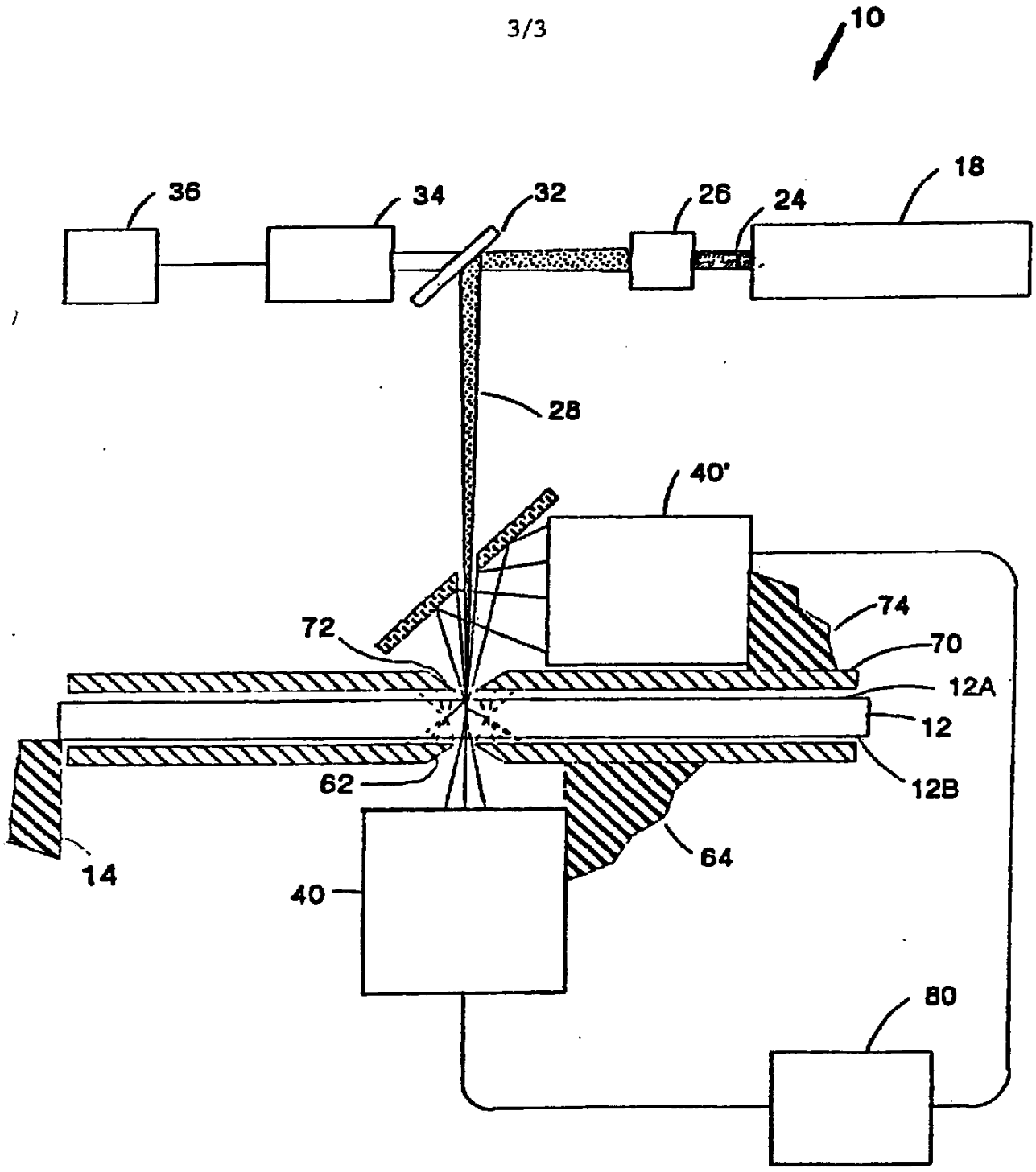

FIGURE 3

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US89/05297

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.[5] G 03 B 42/08 US 250/327.2

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
US	250/327.2D, 327.2E, 327.2F, 484.1B

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
Y , P	US, A, 4,797,553 (CARUTHERS, JR.) 10 JANUARY 1989 (10.01.89), see abstract, figure 1).	1, 2
Y	US, A, 4,775,791 (OWEN *ET AL.*) 04 OCTOBER 1988 (04.10.88), see column 3, line 57 to column 4, line 3).	1, 2
A	US, A, 4,742,225 (CHAN) 03 MAY 1988 (03.05.88)).	1, 2
A	US, A, 4,733,090 (DeBOER *ET AL.*) 22 MARCH 1988 (22.03.88)).	1, 2
A	US, A, 4,637,898 (DeBOER *ET AL.*) 20 JANUARY 1987 (20.01.87)).	1, 2
A	US, A, 4,608,190 (BRIXNER) 26 AUGUST 1986 (26.08.86)).	1, 2
Y	US, A, 4,582,988 (AAGANO) 15 APRIL 1986 (15.04.86), see column 7, lines 8-20).	1, 2
A	US, A, 4,543,479 (KATO) 24 SEPTEMBER 1985 (24.09.85)).	1, 2
	[Listing continued on supplemental sheet (2)]	

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
29 AUGUST 1989	06 MAR 1990
International Searching Authority	**Signature of Authorized Officer**
ISA/US	Constantine Hannaher

Form PCT/ISA/210 (second sheet) (Rev.11-87)

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

A	US, E, Re. 31,847 (LUCKEY) 12 MARCH 1985 (12.03.85)).	1, 2
A	US, A, 4,356,398 (KOMAKI *ET AL.*) 26 OCTOBER 1982 (23.10.82)).	1, 2
A	US, A, 4,346,295 (TANAKA *ET AL.*) 24 AUGUST 1982 (24.08.82)).	1, 2
A	US, A, 4,316,817 (CUSANO *ET AL.*) 23 FEBRUARY 1982 (23.02.82)).	1, 2
A	US, A, 4,261,854 (KOTERA *ET AL.*) 14 APRIL 1981 (14.04.81)). [Listing continued on extra sheet]	1, 2

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]

This International search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers , because they relate to subject matter [2] not required to be searched by this Authority, namely:

2. ☐ Claim numbers , because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [3], specifically:

3. ☐ Claim numbers_____, because they are dependent claims not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [2]

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.
2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:
3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:
4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	US, A, 3,975,637 (IKEDO *ET AL.*) 17 AUGUST 1976 (17.08.76)).	1, 2
A	US, A, 3,076,967 (VERNOIS) 05 FEBRUARY 1963 (05.02.63)).	1, 2
A	US, A, 2,642,538 (URBACH) 16 JUNE 1953 (16.06.53)).	1, 2
A	GB, A, 2 096 160 (EASTMAN KODAK COMPANY) 13 OCTOBER 1982 (13.10.82)).	1, 2
A	EP, A2, 0 077 678 (FUJI PHOTO FILM CO., LTD.) 27 APRIL 1983 (27.04.83)).	1, 2
A	EP, A1, 0 152 563 (FUJI PHOTO FILM CO., LTD.) 28 AUGUST 1985 (28.08.85)).	1, 2
	[Listing ends]	